(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 May 2002 (10.05.2002)

PCT

(10) International Publication Number
WO 02/37139 A1

(51) International Patent Classification⁷: G01T 1/20, 1/36

(21) International Application Number: PCT/SE01/02377

(22) International Filing Date: 30 October 2001 (30.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0004012-1 2 November 2000 (02.11.2000) SE

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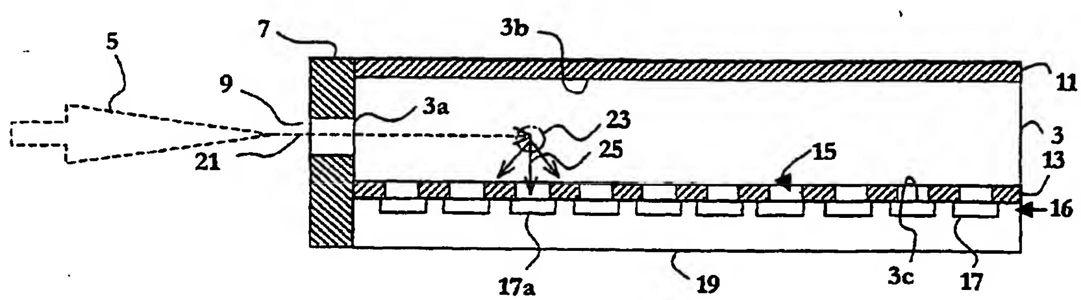
(81) Designated States (*national*): AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *entirely in electronic form (except for this front page) and available upon request from the International Bureau*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SCINTILLATOR BASED DETECTION APPARATUS AND METHOD USING TWO-DIMENSIONAL MATRIX OF LIGHT DETECTING ELEMENTS



(57) Abstract: An radiation detector comprises a scintillating layer (3); a radiation entrance (9); and a light detection arrangement (16) including a two-dimensional matrix of light detecting elements (17), wherein the light detection arrangement is oriented with respect to the radiation entrance such that light (25), being emitted in the scintillating layer in a direction essentially perpendicular to the direction at which the radiation beam is entered into the scintillating layer, is detectable. Further, a grid-like layer (13) including a plurality of light-transparent openings (15) is arranged between the scintillating layer and the light detection arrangement and aligned therewith, such that the respective light-transparent openings (15) are overlying the respective light detecting elements (17).

WO 02/37139 A1

Scintillator based detection apparatus and method using two-dimensional matrix of light detecting elements.

The present invention generally relates to apparatus and methods for detection of ionizing radiation, particularly but not exclusively X-rays, and is usable in a variety of fields including e.g. medical radiology, computerized tomography (CT), microscopy, and non-destructive testing.

DESCRIPTION OF RELATED ART AND BACKGROUND OF THE INVENTION

Scintillator based detection systems are widely used for high-resolution imaging of gamma and x-rays. Such imaging systems use the detected radiation to produce a signal, which can be used to operate a visual display, such as a cathode ray tube.

One example of such radiation detector is disclosed in U.S. Pat. No. 5,144,141. In this detector, radiation incident on the detector passes through a collimator and strikes a scintillator, which is divided into a plurality of scintillator elements arranged in rows and columns. An array of internal photodetectors divided into rows and columns are optically connected to the scintillator elements. Each photodetector is electrically coupled to a respective detect and hold circuit which stores the pulse generated by the photodetector; the stored pulses are sampled via a multiplexed switching arrangement to allow the stored signal from each detect and hold circuit to be processed to produce a digitized imaging signal which corresponds to the energy level of, and location on the array of, the detected incident radiation. The digitized imaging signal is supplied to display memory and analysis equipment for the device.

Improved spatial resolution requires the use of a large number of photodetectors and a scintillator system, which generates light photons only in the scintillator segment in which the incident radiation was absorbed. The use of a larger number of photodetectors in a large array or to increase the resolution of the device rapidly results in very complex and expensive apparatus.

Additionally, the spatial resolution is limited due to the facts that the incident radiation beam is divergent and that the scintillator has to be sufficiently deep (i.e. having a sufficient dimension in the direction of the incident radiation) to absorb a substantial portion of the incoming radiation. Thus, the photons in a particular ray bundle of the radiation beam may get absorbed in different scintillator segments (if the segments are small) and consequently blur the image obtained.

Furthermore, the scintillator light is emitted isotropically and illuminates a large area of the photodetector, hence reducing the position resolution. Besides, photodetectors are sensitive to direct irradiation by the incident X-rays and hence measures have to be taken in order to prevent the incident radiation from reaching the photodetectors.

In US 4,187,427 several x-ray detectors are disclosed. In one embodiment collimators and a front and back wall, respectively, define an array of volumes or detector cells wherein scintillator bodies are arranged. Photo diodes are arranged on top of and underneath each detector cell aligned with the collimators such that light emitted in a scintillator body can be detected by a single one of the photo diodes (Fig. 1; column 4, lines 4-32). A second embodiment comprises a scintillator

body made of a single crystal or other homogenous scintillator material (Fig. 6; column 5, lines 40-47).

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a scintillator based apparatus and method for detection of ionizing radiation, particularly X-rays, which provide for high signal-to-noise ratios and high spatial resolution.

A further object of the invention is to provide such detection apparatus and method, which provide for high sensitivity, and can thus operate at very low X-ray fluxes.

Yet a further object of the present invention is to provide such detection apparatus and method wherein detection elements are arranged so as not to be exposed to direct irradiation by the ionizing radiation.

Still a further object of the invention is to provide such detection apparatus and method, wherein the isotropically emitted light is collimated to illuminate a smaller area of the detector arrangement to further improve the spatial resolution.

Yet a further object of the present invention is to provide such detection apparatus and method, which are effective, fast, accurate, reliable, and of low cost.

These objects among others are, according to the present invention, attained by apparatus and methods as claimed in the appended claims.

By detecting light from a scintillating material in a direction essentially perpendicular to the direction of the incoming radiation several benefits are obtained. Such geometry provides for a very high detection efficiency as the absorption depth may

be made large so as to absorb a major portion of the incoming radiation. An improved spatial resolution is obtained as the perpendicular detection is parallax-free. The light collection as well as the spatial resolution in the inventive detector geometry is improved as the distance between the absorption/interaction region and the detecting elements may be made very short.

By means of the grid-like light absorbing layer light emanating from an interaction volume as a result of the absorption of a particular radiation photon, is mainly detected by a single light detecting element, and thus an improved spatial resolution is obtained.

The detector may be made very thin (from bottom to top), which provides for the stacking of a plurality of detectors to provide a multi-line detector configuration.

The homogenous scintillator layer together with the two-dimensional matrix of light detecting elements enable the use of radiation sources of any divergence, and the arrangement of the detector at any distance from the radiation source, and still being able to perform one-dimensional imaging, and optionally spectrally resolved measurement. It is just a matter of using a single line of light detecting elements transverse to the incident radiation, or if larger signals are wanted, grouping light detecting elements along lines pointing towards the radiation source.

By providing a plurality of detecting elements in a direction perpendicular to the direction of the incident radiation beam one-dimensional imaging may be performed, and by providing a plurality of detecting elements in the direction of the incident

radiation beam energy resolved measurements are capable of being performed.

Further characteristics of the invention and advantages thereof will be evident from the following detailed description of preferred embodiments of the invention, which are shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description of embodiments of the present invention given hereinbelow and the accompanying Figs. 1-4, which are given by way of illustration only, and thus are not limitative of the invention.

Fig. 1 illustrates schematically, in a cross-sectional side view, a scintillator based detection apparatus according to a preferred embodiment of the present invention.

Fig. 2 illustrates schematically, in a cross sectional top view, the detection apparatus of Fig. 1.

Figs. 3a and 3b illustrate schematically, in cross-sectional side views, portions of scintillator based detection apparatus according to two preferred embodiments of the present invention, wherein the spatial resolution obtainable is clearly indicated.

Fig. 4 illustrates schematically, in a front view with collimator portions cut-away, a scintillator based detection apparatus according to a further preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

With reference to Figs. 1 and 2, which schematically, in cross-sectional side and top views, respectively, illustrate a scintillator based detection apparatus, a preferred embodiment of the present invention will be depicted.

The detection apparatus comprises a scintillator 3, the front surface 3a of which being directed towards a planar beam 5 of ionizing radiation to be measured. The scintillator 3 may comprise a solid scintillating substance, a liquid scintillating substance, e.g. liquid xenon or argon, or a scintillating gas, e.g. xenon or argon.

Preferably, the scintillator 3 is formed of a material having a relatively high efficiency for converting the incident radiation to optical energy, a relatively fast decay constant, and good optical transparency. Cesium iodide has proven to be a good scintillator material for the detection of x-rays, having high conversion efficiency, a decay constant of 1 microsecond, and a refractive index of 1.8. Alternatively, other known scintillator materials, such as for instance NaI, BaF2 or polymeric materials, may be used in the scintillator of the present invention.

The scintillator 3 is made of a single relatively scintillator homogenous material, such as e.g. a scintillator body made from a single crystal.

A collimator 7 having an elongated radiation entrance (or alternatively multiple entrances), through which radiation beam 5 is to enter, is arranged in front of scintillator 3. Collimator 7 is typically of lead or tungsten, and the radiation entrance can be divided into a plurality of entrance

openings 9 arranged along a line (Fig. 2), but optionally a single elongated slit opening is provided (not illustrated in Figs. 1 and 2).

Further, a light-absorbing layer 11 is covering top surface 3b of the scintillator 3. Alternatively, layer 11 is light reflective. A patterned, grid-like layer 13 is provided at bottom surface 3c of scintillator 3, which bottom layer thus define a two-dimensional matrix of openings 15 through there. The space in openings 15 may be filled by any suitable light transparent or scintillating material (e.g. same material as in scintillator 3). The layer 13 may be of a light-absorbing or at least partly of a light-reflecting material.

Beneath there is provided a light detection arrangement 16 for detection of light. Arrangement 16 comprises typically a plurality of light detecting elements 17 arranged in a two-dimensional matrix on a substrate 19. Arrangement 16 is aligned with layer 13 such that the respective openings 15 are overlying respective light detecting elements 17.

The light detecting elements 17 may be photodiodes, photosensitive TFT's, photodiode based amplifiers, CCD elements, or other photon counting or light integrating detecting elements.

It shall be appreciated that the light detecting elements 17 (as well as openings 15) may be arranged in a way to compensate for the divergence of any incoming radiation. Thus, the read-out elements may be arranged in a fan-like configuration, wherein each of the elements is aiming at the radiation source of the incoming radiation.

Further, the light detecting arrangement 16 is connected to a signal-processing device (not illustrated) for necessary and/or desired post-processing of collected signal data. Preferably, the read-out elements 17 are thus separately connected to the signal processing circuit by means of individual signal conduits. A signal display unit (neither illustrated) is provided for displaying the processed signal data.

The size of the detection apparatus can vary tremendously depending on the particular application. In a large area array detector, such as would be used for medical imaging purposes, a detection element matrix may typically have a width of up to 50 cm and comprise many thousands of detection elements. A small area array used for some applications may be smaller than 1 mm in width.

In operation, the detection apparatus of Figs. 1 and 2 is positioned in the path of radiation desired to be detected. Rays of incident radiation emanating directly from the subject under examination will travel in a path so as to pass through entrance openings 9 in collimator 7 and enter the scintillator 3, whereas unwanted radiation scattered from the subject under examination towards the detection device will typically travel at some angle to the plane of the collimator and thus will not be able to traverse any of the openings 9. The radiation is preferably X-rays, but the invention is useful with any kind of ionizing radiation that a scintillator is capable of converting into light.

Interactions between the incident radiation and the scintillator material result in the generation of light photons, which are typically emitted isotropically. However, by means of the separation between different light detecting elements 17 and the provision of grid-like light absorbing layer 13 light 25

emanating from an interaction volume 23 as a result of the absorption of a particular radiation photon 21, is mainly detected by a single light detecting element 17a.

In typical detectors, the energy level of the incident radiation ranges between about 10 keV and 500 keV. In this energy range, typical interactions between the incident radiation and the scintillator material include photoelectric absorption and Compton scattering. Both of these processes result in electrons being emitted from atoms in the scintillator that are struck by the incident ray, and as these electrons pass through the scintillator material their energy is converted to visible radiant light energy.

The signals obtained by the light detecting elements 17 are subsequently post-processed and displayed.

By using a transverse array (i.e. parallel with collimator 7) of light detecting elements 17 a detection apparatus is achieved, wherein photons derivable mainly from interactions with transversely separated portions of the planar radiation beam 5 are separately detectable. Hereby, one-dimensional imaging may be performed. Further, by means of grouping light detecting elements, which are located along the direction of the radiation beam 5, and providing a single measured value for each of these groups, an increased signal level and sensitivity may be obtained.

Further, the depth within the scintillator where an interaction between a radiation photon and the scintillating material takes part is governed statistically by the absorption rate of the X-rays in the material used. High-energy X-rays will generally have a larger penetration depth than X-rays of lower energy. Thus, by the provision of multiple detecting elements in the

direction of radiation beam 5, the present scintillator based detection apparatus provides for energy resolved detection of ionizing radiation.

By detecting the scintillations in a direction essentially perpendicular to the direction of the incident radiation beam 5 also a number of additional benefits are obtained.

Firstly, the absorption depth may be made large so as to absorb a major portion of the incoming radiation, which provides for a very high detection efficiency. Secondly, an improved spatial resolution is obtained as the perpendicular detection is parallax-free. Thirdly, the light collection in the inventive detector geometry is improved as the distance between the absorption/interaction region and the detecting elements may be made very short. Further, by providing a scintillator material having a relatively high absorption coefficient the detector may be made shorter (in the direction of the incident radiation) than a corresponding gaseous-based detector, which provides for easier alignment of the detector.

Typically, a detector length in the millimeter region may be used. Still further, the detector may be made very thin (from bottom to top), which provides for the stacking of a plurality of detectors to provide a multi-line detector configuration. Typically, a scintillator as thin as 10 µm may be employed. Finally, the detection apparatus of Figs. 1 and 2 provides for good collimation capabilities of radiation beam 5, whereby images contain very small signals originating from scattered radiation within the detector. Thus, an increased signal-to-noise ratio in the images detected, may be obtained.

Next, with reference to Figs. 3a and b, which schematically, in cross-sectional side views, illustrate portions of scintillator

based detection apparatus, aspects on the grid-like layer 13/light detecting element matrix 17 combination of the present invention will be described.

In Fig. 3a the grid-like layer 13 is not very thick (i.e. having not a very large vertical dimension in Fig. 3a) and made of a light absorbing material. Thus light emitted from an interaction volume 23 as a result of absorption of a particular radiation photon 21 within a given angle α will pass through the opening 15 of the layer 13 and be detected by a single light detecting element 17a.

As the light is emitted isotropically there will be also light propagating within the angle β, which will "see" a neighboring light detecting element. This amount is however small in comparison to the amount of light emitted within the angle α. Further, only some of the light within the angle β will be detected by the neighboring light detecting element since light is tending to be reflected at the surface due to the small incident angle γ between that light and the surface (schematically indicated in Fig. 3a by the dashed arrow).

Thus, as a result of the geometrical discrimination of light emitted in inappropriate directions a very good spatial resolution may be obtained. Note that since the light detecting elements are provided in a two-dimensional matrix, the angles are in fact solid angles or similar three-dimensional angle distributions.

It shall be appreciated that if the distance between the volume 23 and the light detecting element 17a and/or the thickness of the grid-like layer 13 is increased one will reach an operation

mode when no light at all from region 23 will be detected in a neighboring light detecting element.

In Fig. 3b the grid-like layer 13 is relatively thick and surfaces 13a thereof facing the respective openings 15 are made of a light-reflecting material. Thus, not only light emitted from the interaction volume 23 within a given angle α_1 will pass through the opening 15 of the layer 13 and be detected by a single light detecting element 17a, but all light within a larger angle α_2 will pass through one of the openings – directly or by means of a single or multiple reflection(s) at surface(s) 13a. Note that still small fractions of light may find their way towards a neighboring light detecting element.

Preferred dimensions may for instance include a scintillator thickness (i.e. dimension from the light absorbing layer 11 to the grid-like layer 13) of between about 10 µm and about 3 mm, preferably between about 10 µm and about 1 mm; a collimator radiation entrance height (i.e. dimension limiting the thickness of a planar radiation beam enterable into the detector) preferably slightly smaller and located such that the radiation is propagating close to the grid-like layer 13), a grid-like layer thickness of between about 10 µm and about 1 mm, and grid-like layer opening widths of less than about 1 mm, preferably less than 100 µm, and more preferably between about 1 µm and about 50 µm.

Next, with reference to Fig. 4, which schematically, in a front view with collimator portions cut-away, illustrates a scintillator based detection apparatus, a further preferred embodiment of the present invention will be described.

This embodiment differs from previous embodiments in the structure and function of the light detecting arrangement 16 only. Here, a photocathode 41 is arranged adjacent scintillator 3, which is arranged such that it releases photoelectrons in dependence on the light photons that hit it. The cathode shall be thin such that it is capable of releasing electrons from the surface opposite to the surface onto which the photons (e.g. those indicated by 25) are impinging.

An electron avalanche amplification arrangement is provided next to photocathode 41 preferably provided with two electrodes; a grid-like avalanche cathode 43 and an avalanche anode 45, and is adapted to collect photoelectrons released from photocathode and to strongly avalanche amplify these. Geometries and amplification material of the light detecting arrangement and electric potentials, at which the photocathode and avalanche electrodes are held, are selected such that a suitable amplification is obtained. For illustrative purposes electrical field lines between a single one of the read-out elements 45a and the photocathode 41 are schematically indicated in Fig. 4 by reference numeral 46.

Preferably, there is provided a closed chamber 47 between the electrodes containing a gas suitable for electron avalanche amplification. Such suitable amplification media include for instance argon, CO2, ethane, and mixtures of argon and isobuthane. Alternatively, liquid or solid electron amplification substances are used. A dielectric 49 may be arranged between avalanche cathode 43 and avalanche anode 45. This could be a gas or a solid substrate carrying cathode 43 and anode 45. Thus, the applied voltages produce a strong electric field in an array or a matrix of avalanche amplification regions 51. The avalanche regions 51 are formed

in a region between and around the edges of the avalanche cathode 43 which are facing each other, and between the avalanche cathode 43 and the avalanche anode 45.

Further, light detecting arrangement comprises a read-out arrangement including a plurality of read-out elements arranged in an array or a matrix electrically insulated from each other, the read-out arrangement being adapted to detect pulses induced by the avalanche electrons and/or correspondingly produced ions. Preferably the avalanche anode is patterned and constitutes read-out arrangement, but a separate read-out arrangement may be provided. Read-out elements 45 are preferably individually connected to a signal-processing device (not illustrated) for necessary and/or desired post-processing of collected signal data. A signal display unit (neither illustrated) is finally provided for displaying the processed signal data.

Preferably, the openings 15 of the grid-like layer 13; the avalanche regions 51 and the anode/read-out elements are aligned and overlie each other. Thus light 25 emitted within a region 23 in the scintillator 3 will travel towards photocathode 41, pass an opening in the grid-like layer 13, hit the photocathode 41, and cause electrons, so called photoelectrons, to be emitted from the backside of the photocathode. Such released electrons are then drifted towards the avalanche cathode and are accelerated (schematically indicated by arrow 53) due to the strong electric field between the avalanche cathode 43 and avalanche anode 45. Such accelerated electrons will interact with other material (e.g. atoms, molecules etc.) within a single one 51a of the avalanche regions 51 and cause electron-ion pairs to be produced. Those produced electrons will also be accelerated in the field, and will interact repetitively with new materia, causing further electron-ion pairs to be produced.

This electron avalanche amplifying process continues during the travel of the electrons towards a single one 45a of the read-out elements 45. In such manner detection of high spatial resolution and high sensitivity may be performed.

The present invention, thus incorporating the homogenous scintillator layer together with the light detection arrangement comprising a plurality of light detecting elements arranged in a two-dimensional matrix, enables the use of radiation sources of any divergence, and the arrangement of the detector at any distance from the radiation source, while still one-dimensional imaging, and optionally spectrally resolved measurement, are possible to perform. It is simply to use a single line of light detecting elements transverse to the incident radiation, or if larger signals are wanted, to group light detecting elements along lines pointing towards the radiation source.

It will be obvious that the invention may be varied in a plurality of ways. Such variations are not to be regarded as a departure from the scope of the invention. All such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the appended claims.

CLAIMS

1. An apparatus for detection of ionizing radiation comprising:

- a scintillating layer (3) adapted to emit light in dependence on being irradiated by radiation;

- a radiation entrance (9) arranged such that a radiation beam (5) can enter said scintillating layer; and

- a light detection arrangement (16) for detecting light emitted in said scintillating layer;

characterized in that

- said light detection arrangement is oriented with respect to said radiation entrance such that light (25), being emitted in said scintillating layer in a direction essentially perpendicular to the direction at which said radiation beam is enterable into said scintillating layer, is detectable;

- a grid-like layer (13) is arranged between said scintillating layer and said light detection arrangement, said grid-like layer (13) comprising a plurality of light-transparent openings (15); and

- said light detection arrangement comprises a plurality of light detecting elements (17) arranged in a two-dimensional matrix, each being adapted for individual light detection independently of the other elements, wherein

- said grid-like layer is aligned with said light detection arrangement such that the respective light-transparent openings (15) are overlying the respective light detecting elements (17).

2. The apparatus as claimed in claim 1, wherein the radiation entrance (9) is arranged such that a planar radiation beam (5) can enter the scintillating layer, and the light detection arrangement is arranged such that light derivable from absorption by transversely separated portions of said planar radiation beam is separately detectable.

3. The apparatus as claimed in claim 1 or 2, wherein the light detection arrangement is arranged such that light derivable from absorption by said radiation beam at different locations along the radiation beam is separately detectable.

4. The apparatus as claimed in any of claims 1-3, wherein the light detection arrangement is arranged at a first surface (3c) of the scintillating layer and wherein a light-absorbing layer (11) is arranged at an oppositely located surface (3b) of said scintillating layer.

5. The apparatus as claimed in any of claims 1-3, wherein the light detection arrangement is arranged at a first surface (3c) of the scintillating layer and wherein a light reflecting layer (11) is arranged at an oppositely located surface (3b) of said scintillating layer.

6. The apparatus as claimed in any of claims 1-5, wherein the light detecting elements are photodiodes, photosensitive TFT's, photodiode based amplifiers or CCD elements.

7. The apparatus as claimed in any of claims 1-6, wherein the light detection arrangement (16) comprises a photocathode avalanche amplification arrangement.

8. The apparatus as claimed in claim 7, wherein said photocathode avalanche amplification arrangement comprises:

- a photocathode (41) adapted to release photoelectrons in dependence on light emitted in said scintillating layer and subsequently impinged onto said photocathode;

- an electron avalanche amplifier (43, 45, 47, 49, 51) adapted to avalanche amplify said photoelectrons; and

- a read-out arrangement (45) adapted to detect said avalanche amplified electrons.

9. The apparatus as claimed in Claim 8, wherein the electron avalanche amplifier includes an array of avalanche amplification volumes (51) filled with an avalanche amplification medium.

10. The apparatus as claimed in claim 9, wherein the individual avalanche amplification volumes (51) are separated from each other by a dielectric (49).

11. The apparatus as claimed in any of claims 7-10, wherein the photocathode avalanche amplification arrangement includes an electron permeable avalanche cathode (43) and an avalanche anode (45).

12. The apparatus as claimed in any of claims 1-11, wherein said scintillating layer (3) is of a homogenous material.

13. The apparatus as claimed in any of claims 1-12, wherein said scintillating layer (3) has a dimension in said direction essentially perpendicular to the direction, at which said radiation beam is enterable into said scintillating layer, in a submillimeter region.

14. The apparatus as claimed in any of claims 1-13, wherein said grid-like layer (13) has a dimension in said direction essentially perpendicular to the direction, at which said

radiation beam is enterable into said scintillating layer, in a submillimeter region.

15. The apparatus as claimed in any of claims 1-14, wherein said light-transparent openings of said grid-like layer (13) have light-reflecting sidewalls.

16. The apparatus as claimed in any of claims 1-14, wherein said light-transparent openings of said grid-like layer (13) have light-absorbing sidewalls.

17. The apparatus as claimed in any of claims 1-16, wherein said light-transparent openings have each a width of less than 1 mm, preferably less than 100 μm, and more preferably between about 1 μm and about 50 μm.

18. An apparatus for detection of ionizing radiation comprising a plurality of the detector as claimed in any of claims 1-17 arranged in a stacked configuration to provide a multi-line detector configuration.

19. A method for detection of ionizing radiation in a radiation detector comprising a scintillating layer (3), a radiation entrance (9), and a light detection arrangement (16) including a plurality of separated light detecting elements (17) arranged in an array, said method comprising entering a radiation beam (5) through said radiation entrance and into said scintillating layer, wherein said scintillating layer emits light in response to said entered radiation, characterized by the steps of:

- entering a radiation beam into said scintillating layer; and

- detecting light emitted in said scintillating layer in a direction essentially perpendicular to the direction, at which

said radiation beam is entered into said scintillating layer, by means of said plurality of separated light detecting elements (17), wherein

- light emanating from an interaction volume 23 as a result of the absorption of a particular radiation photon 21 is passing through a single one of a plurality of light-transparent openings (15) comprised in a grid-like layer (13) arranged between said scintillating layer and said light detection arrangement; and is mainly detected by a single one (17a) of said plurality of separated light detecting elements.

20. The method as claimed in claim 19, wherein a planar radiation beam (5) is entered through the radiation entrance and into the scintillating layer, and wherein light derivable from absorption by transversely separated portions of said planar radiation beam is separately detected.

21. The method as claimed in claim 19 or 20, wherein light derivable from absorption by said radiation beam at different locations along the radiation beam is separately detected.

22. The method as claimed in any of claims 19-21, wherein light emitted in the scintillating layer is detected by means of:

- releasing photoelectrons in dependence on said light emitted in the scintillating layer by means of a photocathode (41);

- avalanche amplifying said photoelectrons by means of an electron avalanche amplifier (43, 45, 47, 49, 51); and

- detecting said avalanche-amplified electrons by means of a read-out arrangement (45).

23. The method as claimed in any of claims 19-22, wherein said scintillating layer (3) is of a homogenous material.

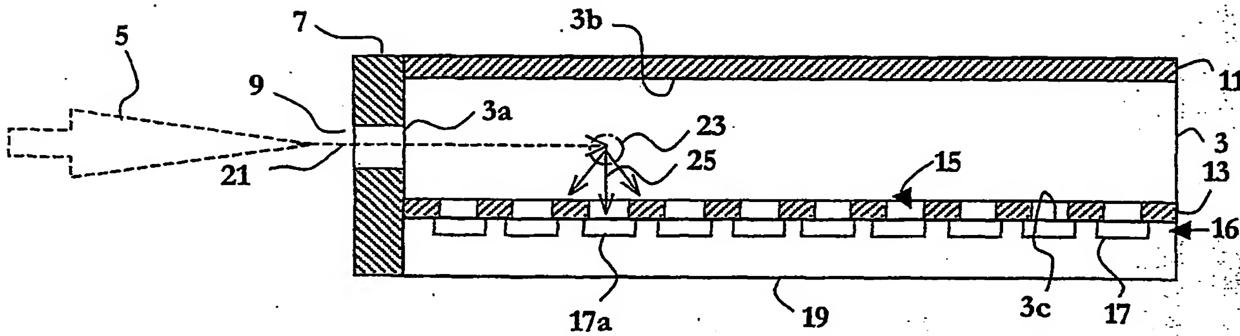


Fig. 1

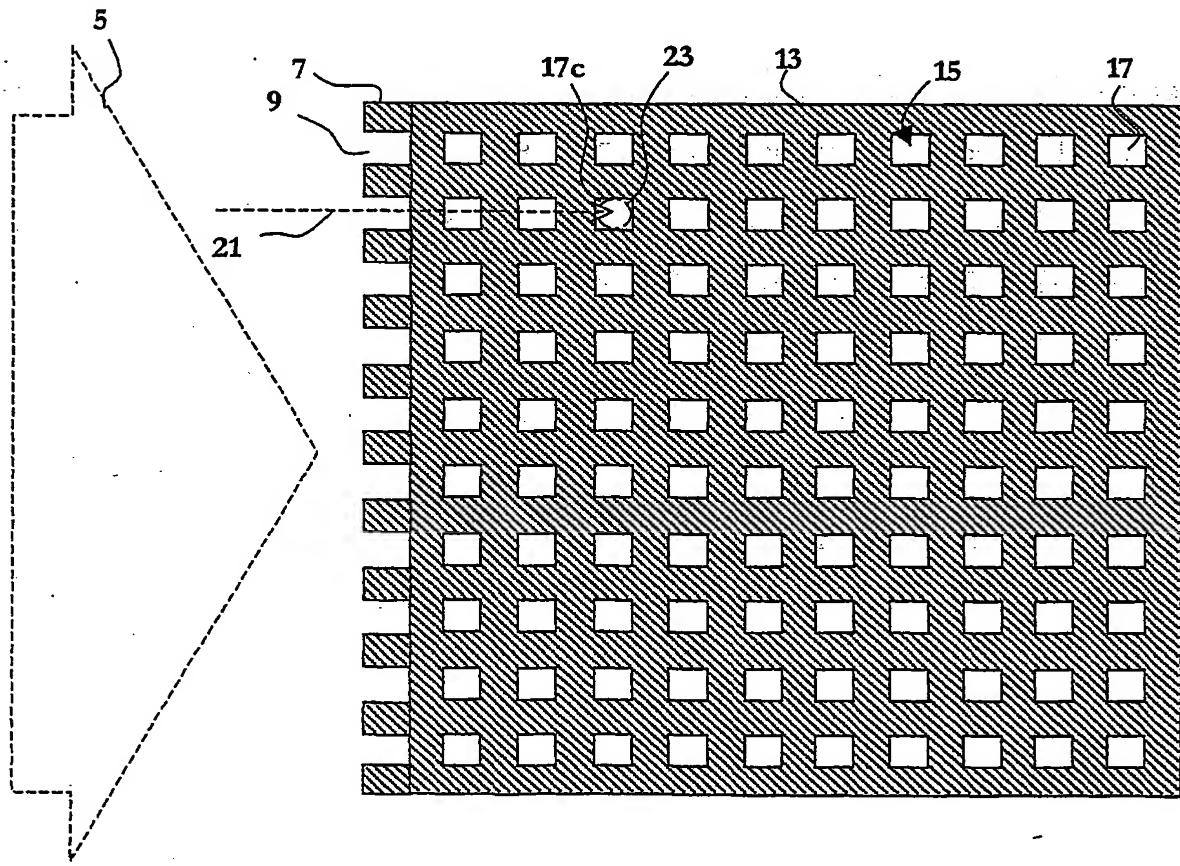


Fig. 2

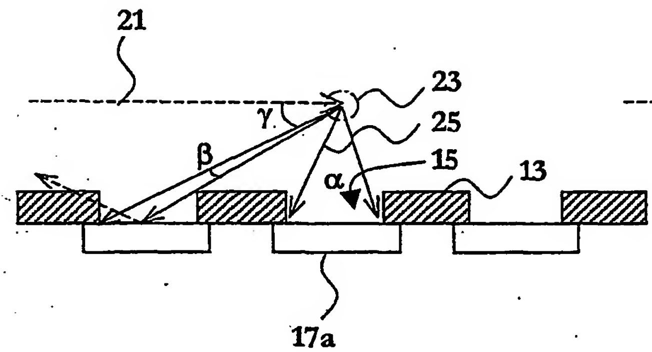


Fig. 3a

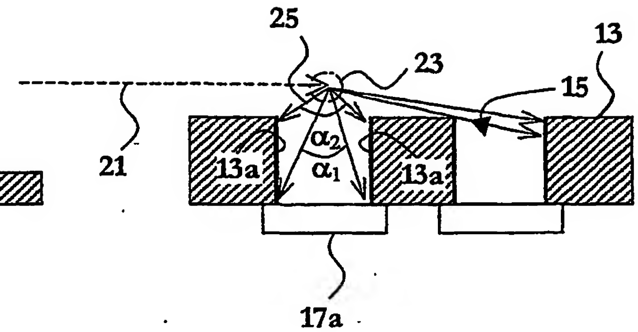


Fig. 3b

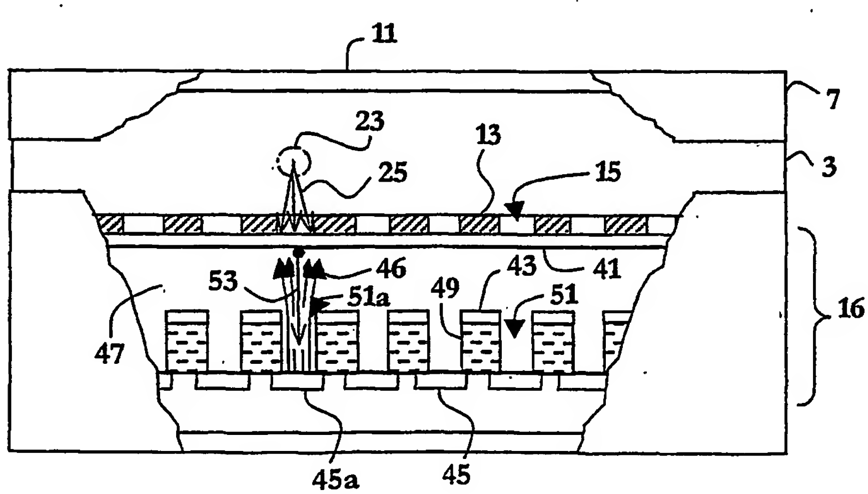


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/02377

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01T 1/20, G01T 1/36
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 3827976 A1 (ISOTOPENFORSCHUNG DR. SAUERWEIN GMBH), 22 February 1990 (22.02.90), column 6, line 47, figure 3 --	1-23
A	EP 0637084 A1 (GENERAL ELECTRIC COMPANY), 1 February 1995 (01.02.95), figure 1, abstract --	1-23
A	FR 2625331 A1 (JEAN-JACQUES WALTER), 30 June 1989 (30.06.89), figure 2 --	1-23

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 February 2002	18-02-2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Sture Elnäs/mj Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	US 6167110 A (GEORGE EDWARD POSSIN ET AL), 26 December 2000 (26.12.00), figure 2, abstract --	1-23
A	US 5539206 A (THOMAS R. SCHIMERT), 23 July 1996 (23.07.96), figure 5 -- --------	1-23

INTERNATIONAL SEARCH REPORT

Information on patent family members

27/12/02

International application No.
PCT/SE 01/02377

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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EP 0637084 A1	01/02/95	DE 69417317 D,T	14/10/99
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		US 5585280 A	17/12/96
FR 2625331 A1	30/06/89	FR 2626679 A	04/08/89
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		EP 0824762 A	25/02/98
		JP 11504763 T	27/04/99
		NO 974814 A	17/10/97
		WO 9633515 A	24/10/96